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FLUID FLOW BALANCING SYSTEM

FIELD OF THE INVENTION

The present invention pertains to the field of fluid flow control.

BACKGROUND

Various types of damper devices have been developed over the years to control the flow of fluid through ducts in HVAC systems. The damper devices are used to control the flow of air through the systems' air ducts and range from a simple hand-turnable damper vane often found in residential buildings to motor driven mechanical damper assemblies more commonly used in commercial and industrial structures. Another type of damper device employs an inflatable bladder or bellows to control fluid flow through a duct, and details of particularly useful bladder-type flow control devices and associated systems can be found in U.S. Pat. Nos. 4,545,524 and 4,702,412. One advantage of the bladder-type flow control devices shown in these patents is that they could be easily retrofitted into existing ducts with minimal difficulty.

Another prior art type of damper device is a mechanical damper assembly comprising a short piece of duct in which a damper vane is provided with a shaft that is pivotally mounted for rotation in the short piece of duct. The damper vane is rotated between open and closed positions by a motor mounted to and outside of the duct piece and connected to the damper vane shaft.

The aforesaid type of mechanical damper assembly is somewhat difficult to install in an existing duct. Installation requires the duct piece of the damper assembly to be spliced into the existing duct system. This involves cutting out a length of the existing duct and usually entails the dismantling of the existing duct to enable such cutting and/or assembly of the duct piece between adjacent sections of the existing duct. This dismantling, cutting and reassembling of the ductwork is time consuming and therefore an expensive operation when performed by paid installers.

The damper vanes in prior art mechanical damper assemblies heretofore have been driven by both electric and fluid motors. A drawback of electric damper motors is that often their life cycle is comparatively short and limited, thereby making motor replacement a relatively frequent and expensive maintenance operation. Another problem is that, in systems employing a considerable number of electric motor driven dampers, relatively complicated wiring schemes and transformers are often involved, all adding to the cost and complexity of the overall system. Fluid motors eliminate the electrical wiring problems and often have comparatively longer life cycles, but they too have had drawbacks associated therewith. Even with so-called frictionless diaphragm-type fluid motors, the actuator rods thereof are engaged by bearings and wipers that still hinder free linear movement of the rods. Also, to reduce friction, the rods are made of hardened steel as opposed to less expensive materials.

Furthermore, mass flow sensors are used in a wide variety of applications to measure the mass flow rate of a gas or other fluids. One application in which a mass flow sensor may be used is a mass flow controller. In a conventional mass flow controller, the mass flow rate of a fluid flowing in a main fluid flow path is regulated or controlled based upon a mass flow rate of a portion of the fluid that is diverted into a typically smaller conduit forming a part of the mass flow sensor. Assuming laminar flow in both the main flow path and the conduit of the sensor, the mass flow rate of the fluid flowing in the main flow path can be determined (and regulated or controlled) based upon the mass flow rate of the fluid flowing through the conduit of the sensor.

Two different types of mass flow sensors have traditionally been used, constant current mass flow sensors, and constant temperature mass flow sensors. An example of a constant current mass flow sensor is illustrated in FIG. 1 wherein a fluid flows in a sensor pipe or conduit in the direction of the arrow X. Heating resistors or "coils" R1 and R2 having a large thermal coefficient of resistance are disposed about the sensor conduit on downstream and upstream portions of the sensor conduit, respectively, and are provided with a constant current I from a constant current source **901**. As a result of the constant current I flowing through the coils R1 and R2, voltages V1 and V2 are developed across the coils. The difference between voltages V1 and V2 (V1 -V2) is taken out of a differential amplifier **902**, with the output of the amplifier **902** being proportional to the flow rate of the fluid through the sensor conduit.

At a zero flow rate, the circuit of FIG. 1 is configured so that the resistance value (and thus, the temperature) of coil R1 is equal to the resistance value (and temperature) of coil R2, and the output of the amplifier **902** is zero. As fluid flows in the sensor conduit, heat that is generated by coil R2 and imparted to the fluid is carried towards R1. As a result of this fluid flow, the temperature of coil R2 decreases and that of coil R1 increases. As the voltage dropped across each of these resistors is proportional to their temperature, voltage V1 increases with an increased rate of fluid flow and voltage V2 decreases, with the difference in voltage being proportional to the mass rate of flow of the fluid through the sensor conduit.

An advantage of a constant current mass flow sensor is that it can operate over a wide range of temperatures, is relatively simple in construction, and is responsive to changes in the ambient temperature of the fluid entering the sensor conduit. In this regard, as the ambient temperature of the fluid entering the sensor conduit changes, so does the resistance of each of the coils R1 and R2. However, it takes a relatively long time for the temperature (and thus, the resistance) of the coils R1 and R2 to stabilize in response to a change in the rate of flow of the fluid.

Constant temperature mass flow rate sensors utilise separate and independent upstream and downstream circuits to set the temperature of the upstream and downstream coils to a particular value, or to a particular value over the ambient temperature of the fluid flowing into the sensor conduit. A disadvantage of each of these circuits is that they require a close matching of corresponding circuit elements (i.e., resistors, coils, and amplifiers) in the upstream and downstream circuits.

Therefore, there is a need for a fluid flow balancing system which eliminates the need for mechanical dampers, reduces energy consumption and provides for a quieter system because of reduced obstruction in the air flow.

This background information is provided for the purpose of making known information believed by the applicant to be of possible relevance to the present invention. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a fluid flow balancing system. In accordance with an aspect of the present invention, there is provided an apparatus for controlling a system which includes a fluid conduit network and at least two motors each drivingly engaged with different fluid movement devices, the apparatus comprising: means for providing a speed signal representative of the speed of each motor; means for providing a control signal in response to the speed of each motor; and means for controlling the speed of each motor in response to the control signal; wherein each motor speed is controlled for balancing the rate of fluid movement at an input point and an exit point of the system.

In accordance with another aspect of the invention, there is provided a system for balancing the rate of fluid movement, wherein the system comprises: at least two motors, each in driving relationship with a respective fluid movement device; means for providing speed signals representative of the speed of each motor; a microprocessor, responsive to the speed signal, for generating control signals representative of a set of new speed signals; and variable speed motor controls for controlling the motor speeds in response to the control signals.

In accordance with another aspect of the invention, there is provided a method for controlling a system which includes a fluid conduit network and at least two motors each drivingly engaged with different fluid movement devices, the method comprising the steps of: sensing the speed signal representative of the speed of each motor in the system; generating, by the use of a microprocessor, control signals representing new desired speeds for each motor; and transmitting a command to each motor in response to the control signals, the command adjusting the motor speeds thereby balancing the rate of fluid movement at an input point and an exit point of the system.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a constant current mass flow sensor according to the prior art.

Figure 2 is a schematic drawing of one embodiment of the present invention.

Figure 3 is a logic diagram of one embodiment of the present invention.

Figure 4 is a graph of the application of the system according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a system that enables the balancing of the rate of fluid movement within a fluid conduit network. By adjusting the operation of fluid movement devices within the fluid conduit network, the movement of the fluid within the conduit can be controlled in a manner such that a particular fluid movement device is not impeding the operation of another, resulting in undesirable affects. For example, if an input fluid movement device is operating at a higher level than an extraction fluid movement device, a pressure increase within the fluid conduit system will result thereby affecting the efficiency of the fluid movement devices. With reference to Figure 2, the system **10** comprises a fluid conduit network **20** within which the fluid moves and at least two motors **40** which are drivingly engaged with separate fluid movement devices **30**. The system further comprises at least one variable speed motor controller **50** which controls the speed of the each of the motors. The variable speed motor controller **50** may also include an input means enabling an additional means for the adjustment, for example manual adjustment, of the speed of one or both of the motors **40**. In addition, a microprocessor **60** provides a means for determining adjustments that are required in order to balance the rate of fluid movement within the fluid conduit network **20**. These adjustments are determined based on the comparison of information relating to the desired state of fluid movement within the fluid conduit network in relation to the collected information relating to the present state of fluid movement within the fluid conduit network. The at least one variable speed motor controller provided for controlling each motor within the system is responsive to the adjustments transmitted thereto by the microprocessor and input means, thereby resulting in the balancing of the fluid movement within the fluid conduit network.

Fluid Conduit Network

The fluid conduit network can be any type of network that enables the guided movement of a fluid. For example, a duct network can provide for the controlled movement of air and a pipeline network can provide for the controlled movement of a liquid. A worker

skilled in the art would understand what type of fluid conduit network would be appropriate for allowing the movement of a particular fluid.

The fluid conduit network is a means by which a fluid is transported or moved from one location to another. These locations may be within a particular structure or within a particular geographical area. In one embodiment, the fluid conduit network is a duct network, typically provided in a building or structure that enables the guided transportation of air within the particular structure. In an alternate embodiment, the fluid conduit network is a pipeline which is used to transport a liquid from one site to another, for example a water pipeline which can be installed within a house or within a town or city.

Fluid Movement Device

A fluid movement device (FMD) can be any type of device which moves of a fluid, wherein a fluid movement device must be compatible with the fluid to be moved. For example, a blower or fan would be appropriate for the movement of air and a pump would be appropriate for the movement of a liquid. A worker skilled in the art would understand what type of fluid movement device would be appropriate for the movement of a particular fluid.

In one embodiment, wherein the fluid to be transported is air, a blower may be an appropriate fluid movement device. A blower is a device such as a fan, for causing air to flow through the fluid conduit network and this device is typically installed within the fluid conduit network. A blower may comprise a forward curved centrifugal fan, or may be any other type of blade fan or other device capable of moving air.

Motors

The motors are devices that provide the necessary mechanical power for driving the fluid movement devices. For example, a motor may be electrically powered or may be a combustion type motor, a hydraulic motor or any other type of motor as would be known to a worker skilled in the art. The type of motor can be determined based on the application for which the system is being used. For example, electrical motors may be used in conjunction with an air transfer system as is typically seen in heating, ventilation and air conditioning (HVAC) systems. A worker skilled in the art would understand

how to specify a motor to drive a particular fluid movement device which is to be used in conjunction with a specified fluid conduit network. These specifications may be determined based on parameters including, for example, the power and capacity of a particular motor, the fluid movement capacity of the fluid movement device and the required fluid movement parameters associated with the conduit network.

A motor can be drivingly engaged with a fluid movement device though the use of a pulley system, a shaft system or a gearing system, for example, wherein these systems enable the transmittion of power or torque generated by the motor to the fluid movement device. In one embodiment of the invention, a motor and a fluid movement device are integrated into a single unit, such that the motor is an integral part of the fluid movement device.

Variable Speed Motor Controller

A variable speed motor controller (VSMC) is a means for controlling the speed of a motor in response to a control signal generated by a microprocessor. In addition a VSMC may be capable of providing a signal representative of the speed of a particular motor at any given point in time. Alternately, the signal representative of the speed of a motor, may be provided by a separate device such as a commutation circuit that may be used in combination with electronically commutated motors.

A variable speed motor controller is responsive to a control signal representative of a desired operational speed for the motor and this controller is electrically connected to the microprocessor enabling the transmission of this control signal. A variable speed motor controller subsequently converts this control signal in to a command that can be transmitted to a motor, and then transmits this command to a motor. This command adjusts the speed of the motor to the desired speed which was identified by the microprocessor using the control signal. As would be known to a worker skilled in the art, the control signal may take a variety of forms for example, a modulated or non-modulated signal or an electronic pulse. The design of a variable speed motor controller which is capable of providing the above functions would be known to a worker skilled in the relevant art.

In one embodiment, adjustment of the motor speeds can additionally be achieved in a manual manner by a technician or an individual through the use of an input means, for example. Such input means could comprise two switches, push-buttons or the like, which can have a plus (+) and minus (-) symbol positioned thereon to indicate an increase or decrease in the motor speed, respectively. For example, the input means can enable a technician the ability to perform course adjustments of the motor speeds and subsequently the microprocessor can provide a means for the fine adjustments of the motor speeds, thereby enabling the balancing of fluid movement within the fluid conduit system.

In one embodiment of the invention, the variable speed motor controller is electrically connected to the motor which is also electrically driven. In this embodiment, a command transmitted from the variable speed motor controller to the motor can be, for example, a voltage. This voltage is indicative of the desired speed of the motor and provides the motor with power to function. A worker skilled in the art would understand how to calibrate a variable speed motor controller with a motor, enabling a transmitted command to produce the desired affect on the motor speed, thereby adjusting the flow of the fluid within the fluid conduit system. For example, a manufacturer of a motor can provide a calibration guide that correlates a particular voltage with a particular motor speed. The fluid flow rate can be determined by the correlation of the speed of the motor and the size or capacity of the fluid movement device it is driving. For example, having regard to an air movement system, if the motor speed is assumed to be constant, the flow rate of air enabled by a blower, for example, will increase as the size of the fan associated with the blower, increases. The design of the variable speed motor controller may also take into account the physical size of the controller. In certain applications, the variable speed motor controller will require specific dimensions to be incorporated within an HVAC unit for example.

In one embodiment of the present invention, the variable speed motor controller comprises a low voltage controller which is used for commanding a high voltage circuit board wherein the motors are electrically connected to this high voltage circuit board. The low voltage controller can provide a predetermined number of motor adjustments wherein one adjustment is a portion of the full range of operational speed of the motor. These motor adjustments can be designed to enable equal increments of motor speed

adjustment for better control during the air flow balancing procedure. For example, if the there are 32 motor speed adjustments provided by the low voltage controller and the minimum air flow provided by the fluid movement device at the lowest motor speed setting is 30 cfm (cubic feet per minute) and the maximum air flow rate is 200 cfm at the highest motor speed setting, the low voltage controller, though the adjustment of the speed of the motor, is capable of increasing or decreasing the airflow within the system by increments of approximately 5 cfm,.

Microprocessor

The microprocessor is a means for providing a control signal to the variable speed motor controller for controlling the operational speed of each motor and hence the fluid movement devices associated therewith. The microprocessor additionally performs actions based on a software application in order to generate these control signals. A control signal is determined based on the desired fluid flow rate within the fluid conduit network and the present state of fluid flow within the network. The present state of fluid flow within the network can be determined based on the speed of the motors powering the fluid movement devices which can be supplied by the variable speed motor controller or other motor speed detection device, for example.

The microprocessor comprises a number of components which enable it to perform the assigned functions. For example a microprocessor for use with the present invention may comprise a central processing unit (CPU), read only memory (ROM), random access memory (RAM), an arithmetic logic unit (ALU) and a data bus to transfer information between these components. A worker skilled in the art would understand how to select a microprocessor which would be compatible for use with the present invention. Considerations may include, computational speed, interconnectivity with external devices and components, memory capacity and physical dimensions, for example.

In one embodiment of the invention, fluid flow rate meters are installed within the fluid conduit system in order to determine the operational fluid flow rate at one or more locations. Based on the operational flow rates of the fluid within the fluid conduit network, the microprocessor can determine the adjustments to the speed of the motors required in order to enable the balancing of the fluid flow rate within the system.

Optionally, the fluid flow rate may be determined in a calculated fashion, based on the speed of the motors, for example. In this case, fluid flow meters may be placed within the fluid conduit network temporarily in order to provide for the calibration of the parameters required for performing these calculations. For example, these required parameters may be fluid flow rate compared with motor speed, voltage applied to the motor compared with motor speed and fluid flow rate relative to desired locations within the fluid conduit network. If for example a gearing system interconnects a motor and a fluid movement device, additional parameters may include the gear ratios compared with the fluid flow rate.

In one embodiment, the system of the present invention is applied to a heating, ventilation and air conditioning (HVAC) system. In this type of system the motors are typically electrically driven, the fluid movement systems are a form of blower or fan and the fluid conduit system is a collection of interconnected ductwork, wherein this ductwork includes at least one intake port for the insertion of fresh air and at least one exhaust port for the removal of stale air.

In embodiment of the present invention, there are two blowers (FMD), wherein one is positioned at an intake point for the insertion of fresh air into the HVAC system and the second blower is positioned at an exhaust point wherein stale air is removed from the system. Efficiency of this system may be improved if the air flow rate into and out of the system is equilibrated. This may be enabled through the adjustment of the motors operating the intake and exhaust blowers, for example. In addition, by balancing the intake and exhaust air flow rate, the noise associated with the operation of the blowers may be minimised.

In one embodiment of the invention, the fluid flow rate within the fluid conduit system is initially determined at a number of positions, wherein each position may correspond to the location of a fluid movement device and can represent additional locations within the fluid conduit network. This fluid flow rate is established at a pre-selected power level for the system, for example, when maximum operational power is applied to each fluid movement device which can be achieved by operating the motors at their maximum operational rotations per minute (RPM). The fluid flow rate at each position can be established by direct measurement of the fluid flow rate or by calculating the

fluid flow rate based on the speed of the motor driving the fluid movement device in the vicinity of the selected position. This calculation is possible provided there is a calibration factor that correlates motor speed with fluid movement rate, for example, wherein this calibration factor can be assigned to a particular fluid movement device by its manufacturer, for example. A worker skilled in the art would understand that various parameters regarding the movement rate of a fluid are dependent on the particular fluid movement device being used. For example, a particular blower model which is installed in a HVAC system will displace a predetermined volume of air at a particular motor speed. Upon the determination of the fluid flow rate at each location, the subsequent step is to equilibrate these fluid flow rates. This procedure will establish corresponding motor speeds for each of the fluid movement devices, thereby providing a balanced fluid flow rate within the fluid conduit network. The microprocessor establishes a difference between the motor speeds that have been determined to provide balanced fluid flow within the fluid conduit network under maximum fluid movement conditions. This difference in the motor speeds determined under maximum fluid movement conditions, is preserved at all other power level settings or fluid movement conditions. In this manner, irrespective of the power level, or fluid movement conditions at which the system is operating, the fluid flow rate will be essentially balanced based on the single balancing procedure performed. Therefore, if the balancing of the fluid flow rate is performed at the High power setting, for example, the microprocessor will automatically apply the same balancing parameters to the Medium, and Low power levels, for example.

To gain a better understanding of the invention described herein, the following examples are set forth. It should be understood that these examples are for illustrative purposes only. Therefore, they should not limit the scope of this invention in any way.

EXAMPLE

USE WITH A HVAC SYSTEM

In one embodiment of the invention, Figure 3 is a logic diagram for the steps used to automatically modify the low power parameter based on the high power balancing, when the HVAC system has two motors and two corresponding blowers. Beginning at block **200** labelled "Controller System Balanced", the first step determines if the flow rate is being adjusted or modified. The flow may be adjusted by a technician or an individual

by simply activating the program mode of the microprocessor. In one embodiment, the variable speed motor controller has input means, for example, two switches or press buttons wherein the speed of the motors can be increased or decreased. If the motor speeds are increased or decreased, the microprocessor will automatically detect a difference in the motors default speed settings and detect an adjustment of the flow rate **210**. At this point, as shown in block **220**, the microprocessor will read the high speed settings for each motor. In step **230**, the microprocessor will determine which motor has the highest speed setting. If High Speed Fan 1 is greater than High Speed Fan 2 then the microprocessor will determine the difference between the high speeds at block **240**. Alternatively, the microprocessor will determine the difference between the high speeds through block **250** since High Speed Fan 2 is greater than High Speed Fan 1. In this manner a positive value is determined for the difference in High Speed fans. Once the difference between the high speed settings of the two fans has been determined at either block **240** or **250**, the low speed setting for the motor with the highest speed will be determined at either block **260** or **270**. Once the low speed is read, the calculated difference in high speed rates, as determined at either step **240** or **250**, is added to the appropriate low speed setting at block **280** or **290**. Through such an addition, the low speed from both motors will be balanced similarly as the high speed settings. The new calculated low speed value will be saved at blocks **300** or **310** and stored in the microprocessor at block **320**. A worker skilled in the art would understand that the updating of any of the speed settings for either of the fans may occur continuously, intermittently or simply prior to the end of the balancing of the flow rates.

In one embodiment, in order to determine the speed of the motors or the Speed Fan as described in the example above, the measurement of the voltage applied to each respective motor can be used as a guide due to its direct relationship with the motor speed. A worker skilled in the art would understand how to determine a conversion factor such that an applied voltage can define a motor speed. For example, this calibration factor can be supplied by the manufacturer of the motor.

In one embodiment of the invention and with reference to Figure 4, the fluid flow balancing system is applied to a HVAC system which has a motor operating an intake blower for inserting fresh air into a duct network and a second motor operating an exhaust blower removing stale air from the network. The bottom graph illustrates the air

flow rate and the top graph illustrates the power applied to the respective motors described above for the HVAC system. Initially, no power is applied to the motors in the HVAC system **400**. Through start-up, power is then applied equally to the motors in the HVAC system resulting in an air flow in the system. The air flow rate slowly increases as the power applied is increased during stage **410**. Through stages **400** and **410**, the flow balancing system of the present invention is not activated. At stage **420**, the flow balancing system is activated, wherein the power to the motors of the HVAC system is increased to maximum power, wherein the air flow increases gradually as the motors increase to maximum power. At stage **430**, the air flow rate is balanced by reducing the power to one or both of the motors of the HVAC system. The power applied to the motors driving the blowers in the HVAC system is modified such that air flow at both the intake and the exhaust ports is at approximately the same level, for example, 150 cubic feet per minute as shown in the bottom graph illustrated in Figure 3. More specifically, according to this example, the power applied to the exhaust blower is reduced during stage **440** since the air flow from the stale air exhaust blower is greater than the air flow at the fresh air intake blower. The measurement of the air flow may be performed using sensors which are interconnected to a microprocessor. Under such an embodiment, the microprocessor can then also automatically adjust the speed of the motors in the HVAC system in order to balance the air flow rate in the HVAC system. Alternatively, the air flow rate can be measured external to the microprocessor through the use of measurement equipment temporally installed at the intake and exhaust ports of the HVAC, wherein this information can be input into the microprocessor for processing.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.